Movement Patterns of Radio-Tagged Adult Humpback Whitefish in the Upper Tanana River Drainage

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Abstract.-- Radio telemetry technology was employed to track the movements and locate important habitats such as feeding, spawning and overwintering areas used by adult humpback whitefish *Coregonus pidschian* in the upper Tanana River drainage. One hundred fifty-nine transmitters were surgically implanted in humpback whitefish from five sample groups during the spring and summer of 2000, 2001, and 2002. Their movements were monitored for several months using boat and aerial tracking techniques. Relocations indicate that adults frequent lake habitats in the spring and early summer, and move from lake to river habitats by mid to late summer. By late fall, most tagged fish were concentrated in two discrete spawning areas; one in the Nabesna River, 15 to 30 km upstream from its mouth, and the other in the Chisana River, 80 to 100 km upstream from its mouth. Most fish overwintered in flowing water habitats, the Tanana and Chisana rivers, while a smaller number overwintered in lakes. Juvenile rearing areas, which are important habitats for any fish population, have not been identified. Locating rearing habitats should be a priority for future studies.

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Introduction

Humpback whitefish *Coregonus pidschian* is the major species targeted in the subsistence fisheries occurring in and adjacent to the Tetlin National Wildlife Refuge in the upper Tanana River drainage. Most subsistence fishing is done by families from the villages of Northway and Tetlin. Case (1986) estimated the average household harvest in Northway to be 170 kg per year. Similarly, Halpin (1987) estimated the average household harvest in Tetlin to be 258 kg per year. While salmon have been documented in the region, they have never been abundant and are not targeted in the fishery (U.S. Fish and Wildlife Service 1990). Residents in the upper drainage have expressed concerns about possible declines in humpback whitefish populations to Tetlin National Wildlife Refuge personnel directly (B. Schulz, U.S. Fish and Wildlife Service, personal communication) and to the Eastern Interior Federal Subsistence Advisory Council as well. The main issue involves a perception that humpback whitefish are less abundant now than they have been in the past.

Addressing local residents' perceptions of reduced abundance of humpback whitefish directly, without baseline information about previous stock status for comparison, is not possible. Data regarding stock or population numbers are not available. Neither spawning nor wintering areas have been identified. Juvenile rearing areas are unknown. Movement patterns within the upper Tanana River drainage, as well as possible migrations far outside the region, have not been confirmed or refuted. Knowledge of important habitats for humpback whitefish in the area, as well as some understanding of their seasonal and annual movement patterns, is required before any real problems can be identified with confidence. Management action intended to remedy identified problems would have to follow. Interpreting movement patterns and recognizing the importance of seasonal locations requires a basic understanding of humpback whitefish biology and life history. A brief synopsis follows.

Humpback whitefish (Figure 1) and their close relatives, referred to by McPhail and Lindsey (1970) as the "*Coregonus clupeaformis*" complex, are widely distributed across northern North

America and Asia. Fleming (1996) presented age distribution data from a spawning population sampled on the Chatanika River in interior Alaska and suggested that median ages were in the neighborhood of 9 or 10 years. Reist and Bond (1988) reported that maximum ages may be as high as 20 years or more on the Mackenzie River in northern Canada. And Power (1978) presented a convincing image of a sectioned otolith from a fish captured in Quebec, which he estimated to be 57 years old. Spawning maturity is reached by 4 to 8 years of age, is variable depending on sex and location, and individuals can spawn multiple times (Alt and Kogl 1973; Alt 1979; Reist and Bond 1988; Fleming 1996). Females may produce 20,000 to 50,000 eggs during each spawning event (Townsend and Kepler 1974; Clark and Bernard 1988). Like all whitefish species, they spawn in freshwater in the fall. However, several different life history scenarios are possible for the species. They inhabit and spawn in large lake systems (Bidgood 1974; Anras et al. 1999), they are found in brackish water near the mouths of the rivers they inhabit (Alt 1979; Reist and Bond 1988), and they migrate along river corridors and spawn in flowing water (Lambert and Dodson 1990; Fleming 1996).

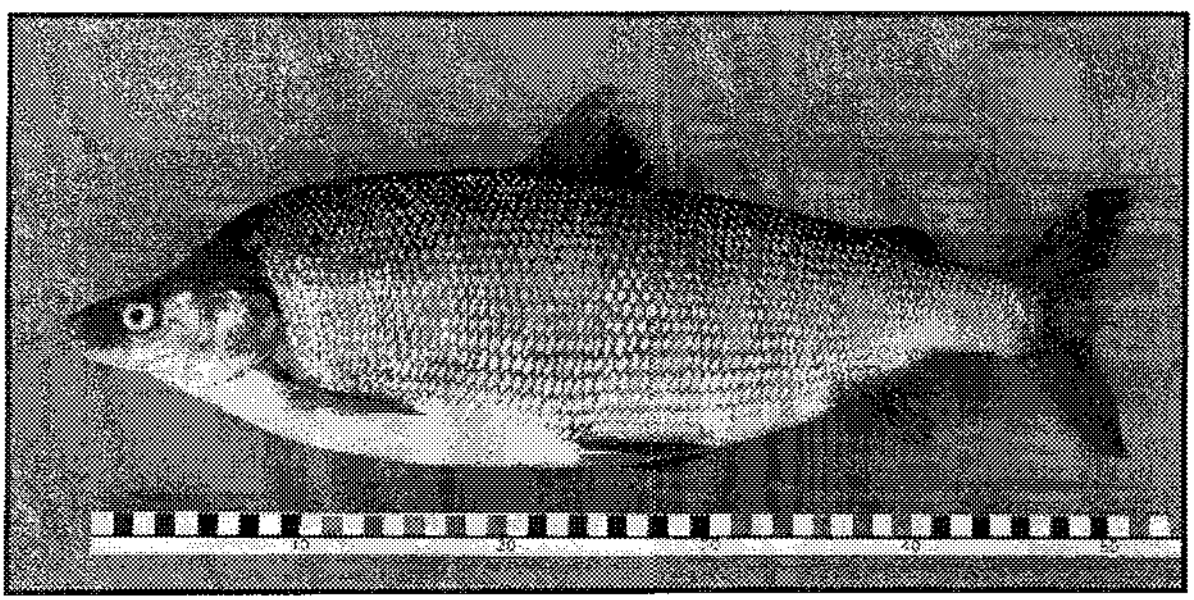


FIGURE 1.—Humpback whitefish *Coregonus pidschian* are medium-sized whitefish in the Family: Salmonidae, Subfamily: Coregoninae. The scale bar is in cm.

Humpback whitefish living in large river systems are thought to follow a generalized life history pattern that Reist and Bond (1988) describe and illustrate very well. The following description leans heavily on their work, with other supporting literature cited as appropriate. Spawning takes place in the late fall in flowing water over a gravel substrate (Alt 1979). Humpback whitefish are broadcast spawners. Eggs are cast into the water column where they drift downstream and sink to the bottom, becoming lodged in the interstitial spaces in the gravel (Scott and Crossman 1973; Morrow 1980). They develop through the winter, hatch in the spring, and emerge into the water column as the high flows of spring and early summer fill the waterways (Naesje et al. 1986; Shestakov 1991; Bogdanov et al. 1992). The tiny juveniles are carried downstream by the rapidly flowing water to a wide array of chance destinations that include backwaters along the river, off-channel lakes, and estuary regions at river mouths (Shestakov 1992). Juveniles that find themselves in habitats that support their needs survive, while others perish.

After several years of growth, young humpback whitefish become mature and prepare to spawn. Beginning in early to mid-summer, they migrate to upstream spawning sites. Like many other coregonid fish, they feed little or not at all for several weeks leading up to spawning (Alt 1969; Dodson et al. 1985). Major spawning areas appear to be used each year, so fidelity to natal spawning areas is thought to be relatively high (Hallberg 1989). Following spawning, adults retreat downstream to overwintering locations (Alt 1979), and eventually to feeding areas by the following spring. Based on tag recapture data, Fleming (1996) suggested that some individuals may spawn on sequential years in the Chatanika River in interior Alaska. However, Lambert and Dodson (1990) calculated the energy demands associated with spawning and contend that it would be nearly impossible to accomplish annually. They proposed instead that the species may actually be spawning every other year or even less frequently. Reist and Bond (1988) concurred, and contended that during the fall spawning period there were three main components of a population: immature fish far downstream of the spawning areas; mature non-spawners also downstream of the spawning areas but not necessarily in the same places as immature fish; and mature spawners at or near upstream spawning areas. Based on these concepts, we might infer that spawning areas are the extreme upstream limit of a population's range, and the rearing areas for immature fish are the extreme downstream limit.

As this project began, some unpublished data were available regarding capture locations for mature humpback whitefish in the upper Tanana River (Bob Schulz, U.S. Fish and Wildlife Service), but movement patterns and important habitats were virtually unknown. Brown et al. (2001) demonstrated that radio telemetry technology could be used with humpback whitefish, and that a year or more of movement data could be collected from individual tagged fish. Combining seasonal locations from radio tagged fish with the basic understanding of humpback whitefish life history promised to provide insight into movement patterns and important habitat areas in the upper Tanana River drainage.

The primary objectives of this project were to locate spawning, overwintering, and feeding habitats used by humpback whitefish in the upper Tanana River drainage, and to identify seasonal migrations of fish between these habitats. Additional objectives were to assess the fidelity of individual fish to certain habitats, explore the presence and behavior of spawning and non-spawning components of the population, and determine the spawning frequency of mature fish. Once achieved, this information will permit informed discussion regarding management options for this important subsistence fishery. This paper describes three years of radio telemetry work with humpback whitefish tagged in four distinct locations in the upper Tanana River drainage.

Study Area

The upper Tanana River drainage, in eastern interior Alaska, is a complex region of inter-connected lake systems, sloughs, and rivers (Figure 2). Wetland areas lie at relatively high elevations, from 500 to 600 m above sea level. The region experiences a continental climate, with cold winters and warm summers (Brabets et al. 2000). Rivers and lakes generally freeze by mid-October and remain frozen until late April or May. Annual precipitation in the region may total 25 cm or more (U.S. Fish and Wildlife Service 1990).

The Nabesna and Chisana rivers flow north from heavily glaciated valleys of the Wrangell Mountains to the south. Flow from these rivers is highly turbid during the summer months and clears somewhat during the winter. The Tanana River originates at the confluence of the Nabesna and Chisana rivers, and shares their annual cycles of turbidity and clarity. These three major rivers, along with an assortment of lakes, sloughs and smaller streams in the region, are the water bodies of interest in this study.

Methods

Radio Telemetry

Radio transmitters used in this study were operated on four frequencies in the 149 MHz range and four frequencies in the 162 MHz range. There were as many as 16 transmitters on each frequency at any one time, but they were digitally coded for unique identification. Radio tags weighed about 9 g, and were approximately 5 cm long and 1 cm in diameter. They were each equipped with a whip antenna about 42 cm long. The transmitters were programmed for two different activity schedules. Most (n=127) were programmed to turn on at the time of surgery and transmit every 3 s for 24 weeks, go dormant for 16 weeks during the winter, and then begin transmitting again until the battery expired. They were expected to last for approximately 13 months, providing a year-long record of seasonal movements. A smaller group of transmitters (n=32) were programmed to transmit for 2-week periods during late September (spawning period), late January (overwintering period), and late May (spring feeding period) for 3 years. These were expected to provide information on annual fidelity to important habitats, and to determine spawning frequency of tagged fish.

Humpback whitefish were captured for tagging at four different locations in the upper Tanana River drainage: the mouth of the Kalutna River, Fish Lake, Tenmile Lake, and in the Scottie Creek wetlands (Figure 2). Transmitters were surgically implanted into a total of 159 fish from the four sites. One hundred and twenty-seven 13-month duration transmitters were deployed as follows: 32 from the Kalutna River in July, 2000; 31 from Fish Lake in late May, 2001; 32 from Tenmile lake in early June 2001; and 32 from the Scottie Creak wetlands in late May 2002 (Table 1). Thirty-two 3-year duration transmitters were deployed from Tenmile Lake in early June, 2002 (Table 1). Morris et al. (2000) suggested that water temperatures greater than 16°C could reduce survival in coregonid fish following surgery. Hence, implantations were conducted only when fish could be released into water colder than this. Monofilament gillnets with 5-cm or 10-cm stretch mesh webbing were utilized for fish capture. Approximately 5 m of netting was set and constantly monitored until a fish struck the net, at which time the fish was disentangled, placed into a tub of water, and evaluated for tagging. Adult fish appearing to be unhurt by capture were considered to be suitable candidates for tagging.

Candidate fish were anesthetized and prepared for surgery immediately following capture. They were placed directly into a clove oil anesthetic solution as described by Anderson et al. (1997). The clove oil was diluted in solution to a concentration of 20 mg/L during the 2000 tagging season, and was increased to 25 mg/L for all later work. Both of these anesthesia solutions were lower in concentration than Anderson et al. (1997) reported using. Fish were considered to be fully anesthetized when they lost equilibrium, rolled over, and ceased active resistance. Weight and fork length were recorded from sedated fish, and they were then ready for surgery.

Radio transmitters were surgically implanted in candidate fish as described by Winter (1996). Anesthetized fish were placed ventral side up in a padded, V-shaped tagging cradle and provided with a constant stream of water over their gills. Anesthesia solution bathed the gills until the first suture was tied. Fresh water was then used until the surgery was complete. All surgical tools, as well as the radio transmitters themselves, were soaked in an antibacterial wash and then rinsed in distilled water prior to use. Scales were removed from the incision area, anterior to the pelvic fins and just to the fish's left of center. An incision, approximately 2 cm long, was then made through the belly wall parallel to the long axis of the fish. A grooved director, a narrow metal device about 10 cm long, was inserted into the fish's body cavity towards the vent. A 25 cm long, flexible, hypodermic needle was then inserted through the belly wall posterior to the pelvic fin, its tip meeting the grooved director inside. The needle was then pushed along the grooved director, which protected internal organs from the sharp needle tip, until the needle emerged from the incision. The transmitter antenna was then threaded into and through the needle, the needle and grooved director were removed, the transmitter was inserted into the body cavity, and the antenna exited the body through the posterior needle hole. The incision was closed with monofilament sutures following a simple interrupted pattern, as recommended by Wagner et al. (2000). Most fish required three stitches for adequate closure. A tissue adhesive compound was applied to the wound line and the suture knots as a final step. Upon completion of surgery, fish were placed into a tub of water to recover. Once upright position was achieved, fish were released. Total time from capture to release averaged about 12 minutes for each fish.

Relocation of radio-tagged humpback whitefish was accomplished by boat surveys and aerial telemetry flights at approximately 3 to 4-week intervals. Additionally, a fixed receiving station was established about 150 km downstream from the confluence of the Nabesna and Chisana rivers (Figure 2) to document long-distance emigration from the study area if it occurred. Relocations were linked to GPS coordinates and plotted on topographic maps. Movements relative to previous locations and to the tagging site were calculated following each survey, and critical habitat areas were identified.

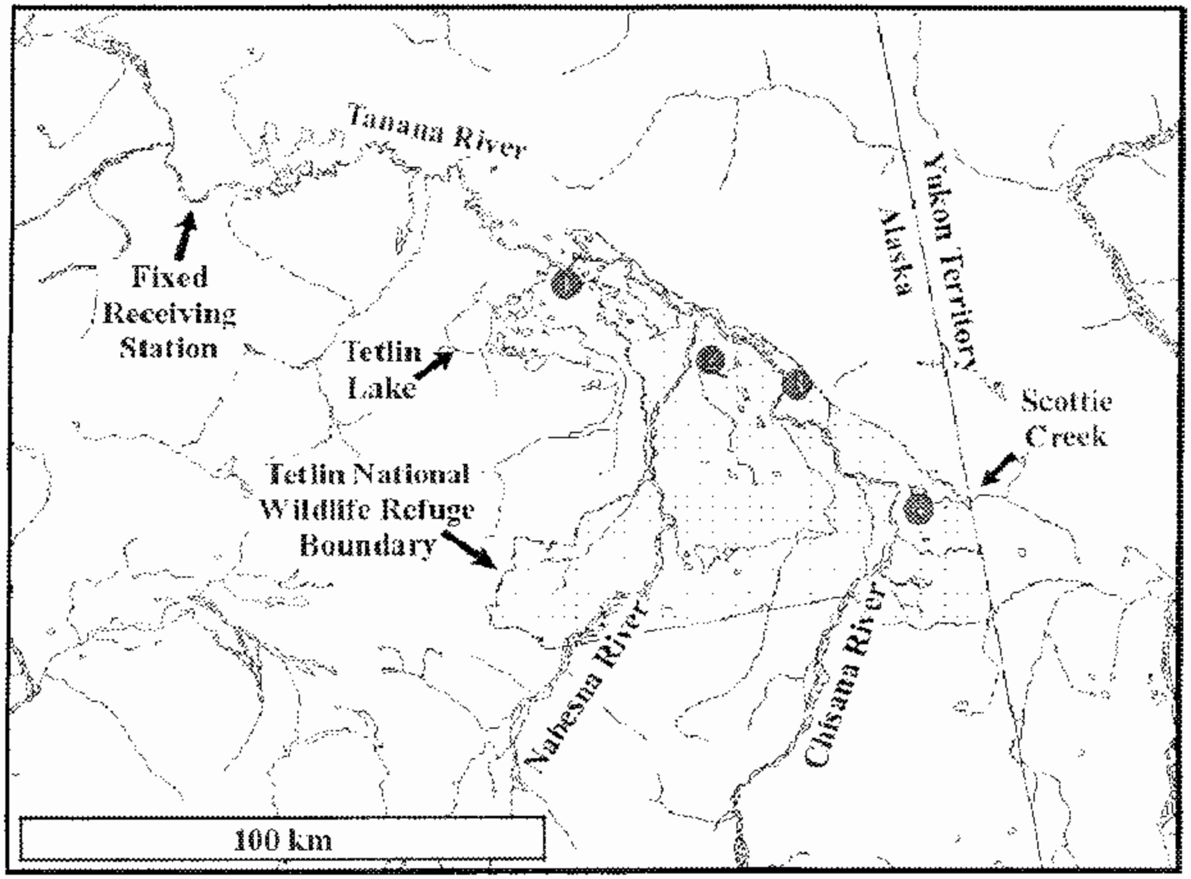


FIGURE 2.—The study area lies in the upper Tanana River drainage in the eastern interior of Alaska. The tagging sites are indicated by the numbered circles. Number one indicates the Kalutna River site, number two the Fish Lake site, number three the site at which the 2001 and 2002 Tenmile Lake tagging events occurred, and number four the Scottie Creek site.

TABLE 1.—Radio-tag deployment data among the five sample groups of humpback whitefish from the upper Tanana River. Length and weight distributions, and length distribution data from spawning humpback whitefish sampled on the Nabesna River (this study) and the Chatanika River (Fleming 1996).

	Sample	Length (cm)		Weight (kg)	
	(*n*)	Median	Range	Median	Range
Kalutna River	32	43.0	39 to 51	1.10	0.85 to 1.66
Fish Lake	31	44.0	40 to 49	1.08	0.84 to 1.47
Tenmile Lake (2001)	32	46.0	39 to 51	1.34	0.87 to 1.79
Tenmile Lake (2002)	32	46.5	37 to 51	1.25	0.75 to 1.80
Scottie Creek	32	42.0	38 to 45	0.90	0.65 to 1.78
Total tagged fish	159	44.0	37 to 51	1.10	0.65 to 1.80
Nabesna samples	215	40.0	33 to 51	—	—
Chatanika River	1,513	44.0	36 to 56	—	—

Nabesna River Spawning Area Survey

The Nabesna River spawning area was visited from September 25 to 27, 2002, to verify that humpback whitefish in the area were in spawning condition and to determine if non-spawning fish were also present. The objective was to capture and evaluate the spawning condition of at least 200 humpback whitefish. A 90 m beach seine with 3 m depth and 1 cm mesh size was used for capture. The beach seine was set from a boat. One end was tied to shore and the rest of the net was piled into the front of the boat in such a way that it would feed into the water as the boat backed away. The boat backed off shore for 15 m or so, turned downstream parallel to shore for approximately 50 m, then the end of the net was taken back to shore and hauled onto the beach, encompassing a volume of river and any fish that might be present. The beach seine was slowly hauled to shore from the upstream end until fish could be taken from it with a dip-net. Sampling sites were selected based on the presence of radio-tagged fish in the vicinity and a suitable bank for setting a beach seine. Beach seines were set at four sites that were widely distributed within the spawning area.

When humpback whitefish approach spawning time, a number of detectable physiological changes occur. The testes of males swell and turn from a reddish color to white. The swelling is minor relative to body size, so the body does not become swollen or distended. Distinct tubercles, or bumps, develop on scales along the lateral sides of spawning condition males, as well as across their heads (McPhail and Lindsey 1970; Vladykov 1970). When spawning males are handled, milt flows from the vent (Snyder 1983). The egg masses of females expand greatly within the body cavity, becoming as much as 15% or more of the total body mass (Bond and Erickson 1985, Clark and Bernard 1988). Females in this condition are referred to as gravid, and the body cavity appears to be highly distended or swollen. When spawning females are handled, eggs flow freely from the vent (Snyder 1983). Spawning condition females also develop breeding tubercles, but they are not as distinct or abundant as those on the males (McPhail and Lindsey 1970; Vladykov 1970).

Spawning condition and sex of captured humpback whitefish were evaluated based on external examination. The presence and distinctiveness of tubercles, flowing milt or eggs, and normal or distended body form were used to determine whether fish were preparing to spawn or not. These same criterion were used to determine the sex of each fish. All fish were released following examination.

Results

Radio Telemetry

All radio-tagged fish appeared to be mature adults. The overall median length of tagged fish was 44 cm, and ranged from 37 cm to 51 cm (Table 1). The overall median weight was 1.10 kg, and ranged from 0.65 kg to 1.80 kg (Table 1). Sex could not be confidently determined by outward appearance in the spring and early summer when the tagging events took place. However, 10 radio-tagged fish were known to be female, because eggs were observed in the body cavity during surgery. The sexes of the other 149 fish were undetermined.

Radio-tagged humpback whitefish were located by a regular series of boat and aerial telemetry surveys. Rarely were all fish located on any one survey. However, when the results of multiple surveys were considered together, the seasonal movement patterns of nearly all tagged fish became clear.

Generalized movements by season, habitat, and upstream or downstream trends occurred for all groups of fish, and were similar among groups. No fish were recorded moving downstream past the remote receiving station, showing that mature humpback whitefish tagged in this study restricted their migrations to the upper part of the Tanana River drainage. The Kalutna River fish were tagged at the confluence of the Kalutna and Tanana rivers in July, so their locations in the spring were unknown. However, during the following spring, 28 of the original 32 fish were located in Tetlin Lake (Figure 2). The fish from Fish Lake, Scottie Creek, and both 2001 and 2002 Tenmile Lake tagging events were captured in lakes in late May or early June. Following is a synopsis of seasonal movement patterns and locations of important habitats as determined from relocations of radio-tagged humpback whitefish during the course of this study.

Adult humpback whitefish inhabit lake systems in the upper Tanana River valley each spring and early summer. A few radio-tagged fish moved between lake and river habitats during this early season, but most fish remained in the lakes, which are thought to be utilized for feeding (Figure 3a). During mid to late summer, radio-tagged fish made a distinct move from lake to river habitat. They distributed themselves widely along the river system with concentration areas in the vicinities of their respective lake outlets, and also near the confluence of the Nabesna and Chisana rivers (Figure 3b). By early fall, most fish had moved into the lower reaches of the Nabesna and Chisana rivers, which represented an upstream movement for Kalutna River fish and a downstream movement for the other groups of fish. During late fall, the expected spawning time for humpback whitefish (Alt 1979; Reist and Bond 1988), concentrations of radio-tagged fish were located in the Nabesna and Chisana rivers (Figure 3c). All told, 52 fish were located during the spawning season in a relatively discrete region of the Nabesna River, from 15 to 30 km upstream of the Nabesna River mouth, and 66 fish were located in a similarly discrete region of the Chisana River, from 80 to 100 km upstream from the Chisana River mouth. Fish from all tagging locations were found in both regions, which were considered to be spawning areas. In early winter, radio-tagged fish were located primarily in river habitat downstream from the suspected spawning areas (Figure 3d). Concentration areas seemed to be in the vicinities of their respective lake outlets and near the confluence of the Nabesna and Chisana rivers. The fish tagged at the mouth of the Kalutna River provided an exception to this generalization. About half of these fish were in the Tanana River near the confluence of the Nabesna and Chisana rivers. and the other half had ascended the Tetlin River and were located in Tetlin Lake during the early winter. Additionally, about half of the Scottie Creek fish were within the wetland system in early winter, while the other half were located in the Chisana and Tanana rivers.

A total of 41 fish were not located in the two identified spawning areas during the spawning season and are considered to have been either non-spawning fish, or their spawning disposition was unknown. Fourteen fish were located far from either spawning area during the spawning season and are considered to have been non-spawners (Table 2). Some of these non-spawners were in the lakes in which they were tagged, while others were in various locations along the Tanana and Chisana rivers. Eight fish were not located during the spawning season and it is unknown whether they were spawners or non-spawners. Three fish were harvested before the spawning migration began. And finally, 16 fish tagged in Scottie Creek were located within the wetland system associated with Scottie Creek during the spawning season. However, Scottie Creek is unique among the tagging sites in that it is within 6 km of the area identified as the Chisana River spawning area. Fish could have migrated from the wetlands within Scottie Creek to spawning habitat in a matter of hours. This type of short migration could easily have been missed by the two aerial surveys that were conducted during the spawning season. Therefore, it is unknown whether these fish were spawners or non-spawners (Table 2).

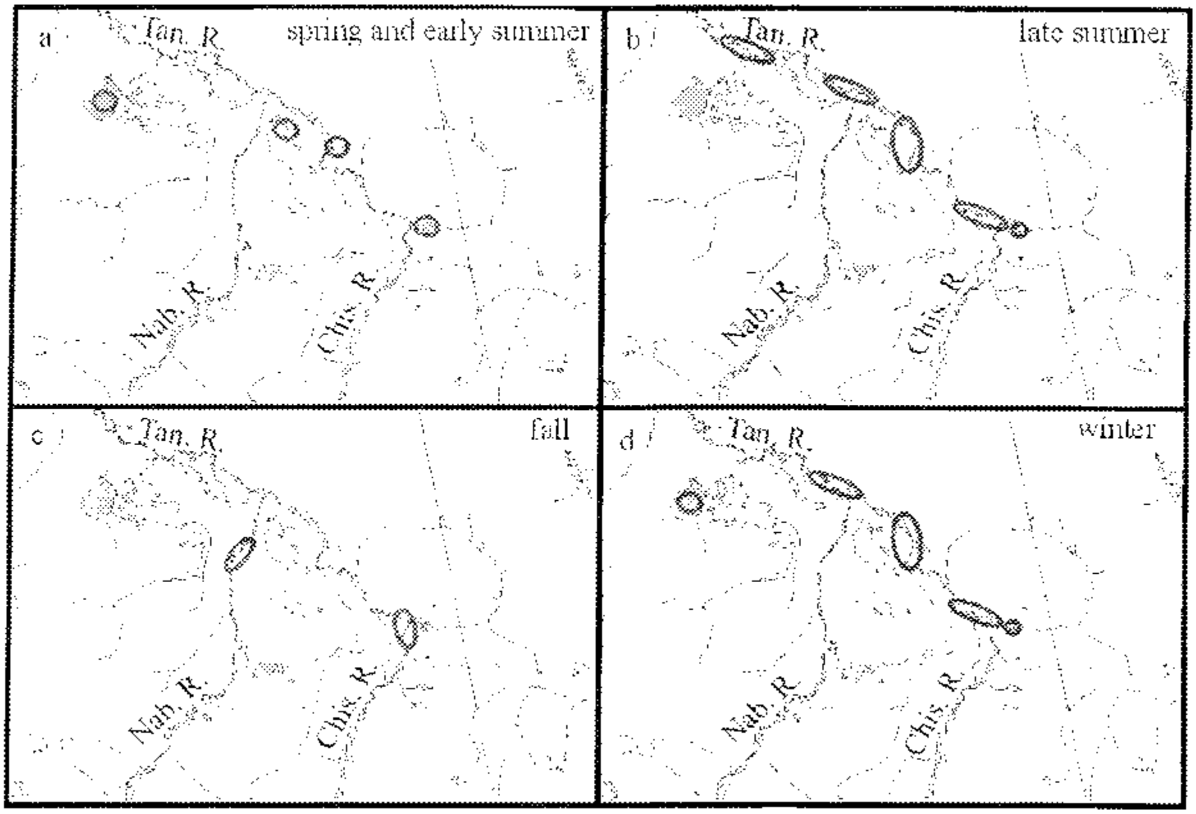


FIGURE 3.—Seasonal movement patterns of radio-tagged humpback whitefish in the upper Tanana River drainage. Abbreviations are as follows; Tan. R. (Tanana River), Nab. R. (Nabesna River), Chis. R. (Chisana River).

Late winter and spring location data are available for three of the five sample groups. Fish from the Kalutna River, Fish Lake, and the 2001 tagging event in Tenmile Lake were tracked through the entire 13 month operational time period of their transmitters. These groups will be discussed in the following section. Fish from the 2002 tagging event in Tenmile Lake and from Scottie Creek are partway through their tracking schedule and cannot be discussed further. In addition to revealing habitat use and migration timing, this information allows an assessment of spring habitat fidelity and annual survival and mortality rates.

Kalutna River fish were apparently active during the winter. They moved from river habitat, up the Tetlin River and into Tetlin Lake during the winter. By spring of the year following tagging, 28 of the original 32 tagged fish were located in Tetlin Lake. Of the remaining four fish, one was harvested in the Nabesna River (Table 2), over 55 km upstream of the tagging location, one disappeared about 3 weeks following tagging, one moved about 50 km downstream after tagging and remained in the Tanana River near the mouth of a small stream through the winter, and one disappeared after being located in the Nabesna River during the spawning period.

TABLE 2.—Known spawning distribution and disposition for radio-tagged humpback whitefish from the five tagging groups. Harvest records are also shown. Sums across categories do not necessarily add to tagged sample sizes because, for example, the fish that was harvested from the Kalutna River group was caught near the Nabesna River spawning area just prior to spawning season and is considered to have been a Nabesna River spawner as well.

Study sites	Chisana spawners	Nabesna spawners	Non-spawners	Unknown	Harvest
Kalutna River (n=32)	5	23		4	1
Fish Lake (n=31)	14	10	4	2	1
Tenmile Lake 2001 (n=32)	17	9	5	1	1
Tenmile Lake 2002 (n=32)	16	8	5	1	2
Scottie Creek (n=32)	14	2		16	
Combined total (n=159)	66	52	14	24	5

Most Fish Lake fish wintered in the Tanana and Chisana rivers. They were widely dispersed and were very sedentary throughout the winter, many remaining in the same location from November through April. Only one fish wintered in Fish Lake, near the outlet stream, through the winter. The following spring, 16 fish reentered the lake, and the one fish that had wintered there left and was located 34 km away in the Chisana River. Eleven fish were located in the Tanana and Chisana rivers, rather than in lake habitat. One fish was located in the Scottie Creek wetlands, and two fish were not located. Based on distinct spring migrations, 28 of the 31 initially tagged fish are known to have survived the winter (Table 3). Only one fish had been harvested.

TABLE 3.—Survival and mortality rates of radio-tagged humpback whitefish through the 13-month operational time period of their transmitters. Possible mortality is the sum of fish known to have died and those that may have died.

Sample group	Known survival		Known mortality		Possible mortality	
	Number	Rate	Number	Rate	Number	Rate
Kalutna River (n=32)	28	0.875	1	0.031	4	0.125
Fish Lake (n=31)	28	0.903	1	0.032	3	0.097
Tenmile Lake 2001 (n=32)	29	0.906	0	0	3	0.094

Similar to the Fish Lake group, the 2001 Tenmile Lake fish wintered in the Tanana and Chisana rivers. They were widely dispersed and were very sedentary throughout the winter, many remaining in the same location from November through April. No fish were located in Tenmile Lake during the winter. The following spring, 28 of the original 32 fish had migrated back into Tenmile Lake. The other four fish were located in the Tanana or Chisana rivers. Based on distinct spring migrations, 29 of the original 32 fish are known to have survived the winter (Table 3). None of the fish had been harvested during the 13-month operational time period of their transmitters. However, in July of the next summer, one fish was harvested near the outlet of Tenmile Lake.

Fish from all the tagging sites occupied similar riverine habitat in the summer, fall, and winter, but appeared to exhibit fidelity to particular lakes in the spring and early summer. Only 7 out of 159 fish have been located in lakes other than the ones they were tagged in (or in the case of the Kalutna River fish, the lake they were located in the following spring). Fish tagged at the Kalutna River mouth migrated into Tetlin Lake during the winter, and were present there the next spring. Only one fish from that group was ever located in another lake system. Only two fish each from the Fish Lake group, the 2001 Tenmile Lake group, and the 2002 Tenmile Lake group had been located in other lake systems. None of the fish from the Scottie Creek group were located in other lake systems. All other fish were either in the river system or in their "home" lake only.

Nabesna River Spawning Area Survey

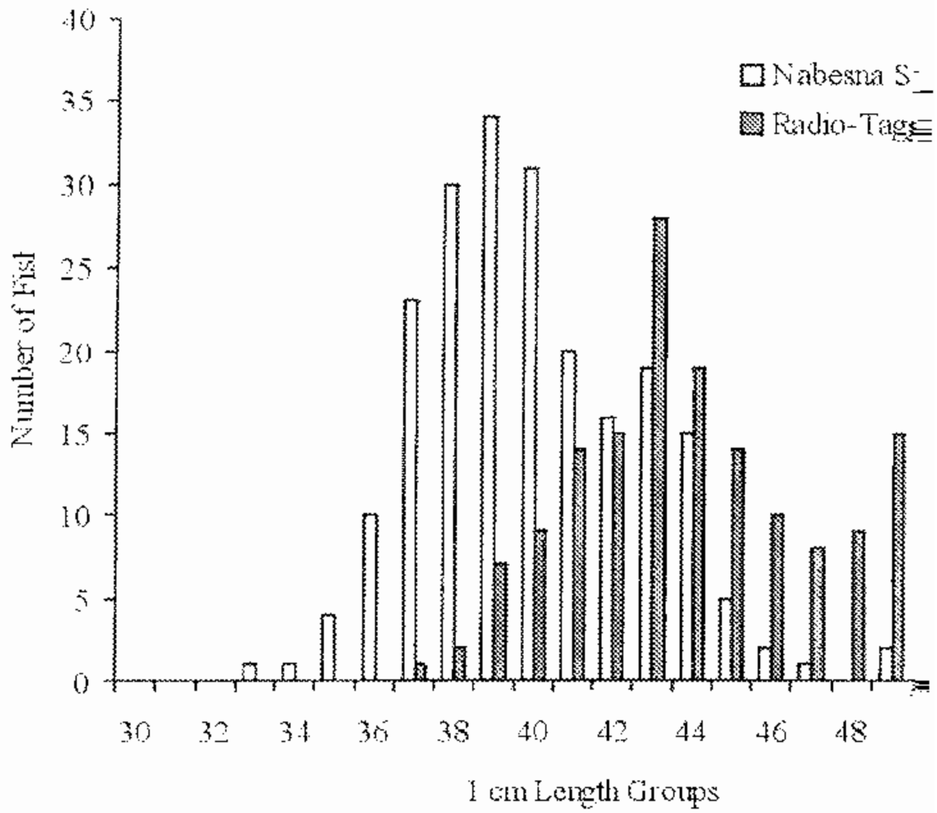
Beach seines were set and hauled at four locations in the Nabesna River spawning area on September 26 and 27, 2002. The largest catch was 219 fish, of which 215 were humpback whitefish, 3 were round whitefish *Prosopium cylindraceum*, and 1 was an Arctic grayling *Thymallus arcticus*. The total catch from the four sets included 396 humpback whitefish, 4 round whitefish, 3 Arctic grayling, and 1 longnose sucker *Catostomus catostomus*.

Spawning condition was evaluated for 394 of 396 humpback whitefish examined in the survey. Two fish escaped before being fully examined. All but one fish from this sample were judged to be in spawning condition. The one non-spawning fish was smaller than the others in the sample and was considered to be immature. Of the 393 humpback whitefish that were judged to be in spawning condition, 21% were male (n=83) and 79% were female (n=310).

Length measurements were recorded for 215 humpback whitefish captured in the Nabesna River spawning area. The median length was 40 cm, and ranged from 33 cm to 51 cm (Table 1). This distribution included a distinctly higher proportion of shorter fish than the radio-tagged sample (Figure 4).

Discussion

At the time of tagging, it was unclear what component of the humpback whitefish population were being sampled; mature spawners, mature non-spawners, immature fish, or a mix of two or more of these groups. There was a striking similarity in the lengths of fish radio-tagged in this study with those reported by Fleming (1996) for humpback whitefish in the Chatanika River spawning area (Table 1). This suggests that mature fish were radio-tagged in the upper Tanana River. A few small humpback whitefish, <30 cm FL, were captured during the project, but they were thought to be too small to accept a radio transmitter and were not tagged. Their presence reveals that at least some immature fish are present in the upper Tanana River drainage.



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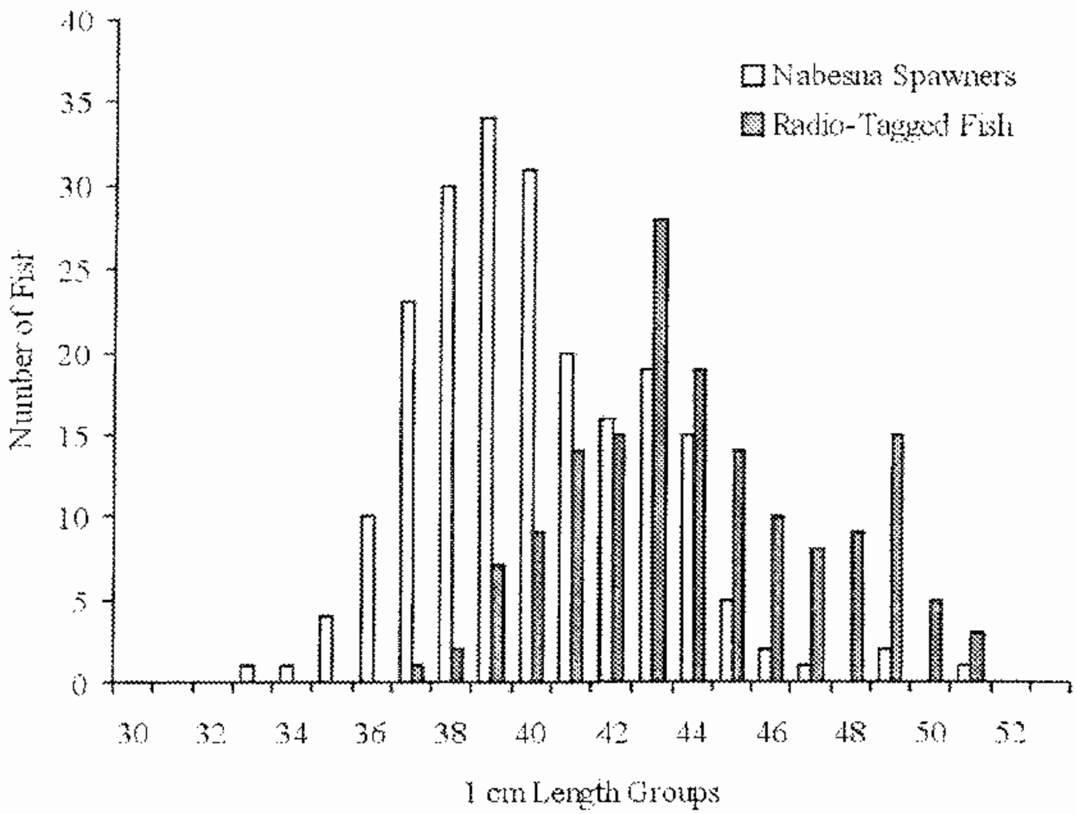

FIGURE 4.—Length distributions of humpback whitefish sampled on the Nabesna River spawning area (n=215), and radio-tagged in the upper Tanana River drainage (n=159).

Important habitats identified during this project include spawning areas, feeding areas, and overwintering areas. The two suspected spawning areas in the Nabesna and Chisana rivers are perhaps the most important discoveries to date (Figure 3c). They are both relatively small regions, each extending for 15 to 20 km along the river. Both areas were used by fish from all tagging locations, and no other region of the upper drainage contained concentrations of tagged fish during spawning season. McPhail and Lindsey (1970) suggested that humpback whitefish may only spawn every second year after becoming mature, a perspective shared by Reist and Bond (1988) and Lambert and Dodson (1990). If this is true, about half of the adult population would be expected to be in spawning condition each fall. However, data from this study is not consistent with this expectation.

A large majority of the radio-tagged fish in this study were located in spawning areas during the spawning season (Table 2), and all the mature fish found on the Nabesna River spawning area were in spawning condition. Furthermore, in the spring of the year following tagging, most radio-tagged fish were present in the same locations where they were initially tagged. Which means that pre-spawning and post-spawning humpback whitefish were both present in the same locations each spring. Barring a catchability bias between pre and post-spawning fish during the spring capture event, the findings of this study indicate that many mature humpback whitefish in the upper Tanana River drainage are spawning on sequential years. The transmitters that were deployed in the 2002 Tenmile Lake fish were designed to transmit for three annual periods. If they perform as expected, they should shed some light on the issue of sequential year spawning, and allow a more informed assessment of this situation.

Lakes that have some connection to the river system in the upper Tanana River drainage are believed to be utilized by humpback whitefish for feeding each spring. Most radio-tagged fish were found in lake habitats in the spring, and a small sample of sacrificed fish from those lakes were found to be feeding on bivalves and gastropods (U.S. Fish and Wildlife Service, unpublished data). Humpback whitefish may feed in the turbid flowing water of the upper Tanana River drainage, where they appear to live for 8 or 9 months each year, but this has not been investigated. Schmidt et al. (1989) found that overwintering coregonid fish on the Arctic coast of Alaska did little if any feeding, regardless of food availability. And Craig (1989) concluded that a majority of annual food reserves were accumulated by Arctic coregonid fish during a 3-month period each summer. Whether or not the humpback whitefish in the upper Tanana River drainage follow the same annual patterns of feeding and fasting as their Arctic counterparts is unknown. This issue should be investigated further.

River habitat appears to be the primary overwintering area for humpback whitefish. Fish from all groups of tagged fish shared habitat in the Tanana and Chisana rivers during the winter. Fish from the Kalutna River group did not stay in one location throughout the winter. Most of them moved from the Tanana River into Tetlin Lake during the winter, a migration of over 50 km, 20 km of which was upstream in the Tetlin River. By contrast, most of the fish from the Fish Lake and Tenmile Lake groups remained at or near the same locations throughout the winter. These behavior differences may be due to lake access issues during the winter months or to winter habitability differences among lakes. Most fish from the Scottie Creek and 2002 Tenmile Lake groups remained in riverine habitats following spawning. Some of the Scottie Creek fish, however, were present within the lake system in the Scottie Creek wetlands, and may remain there throughout the winter. The waterway between the Scottie Creek wetlands and the Chisana River was at least 2 m deep during normal summer flows and may allow fish to move between river and lake habitats during winter. By contrast, the waterways between Tenmile Lake and the Chisana River, and between Fish Lake and the Chisana River, were less than 0.5 m deep in normal summer flows and may not allow winter movement between habitats.

In a study conducted in 1994, Fleming (1996) estimated the annual survival rate of an exploited humpback whitefish population in the Chatanika River to be 0.85, with a 95% confidence range from 0.72 to 0.96. He points out that during other years the estimated annual survival rate has been as low as 0.50. Most of the estimated mortality to the Chatanika River population was from natural causes rather than fishery related (Fleming 1996). The known annual survival rates of radio-tagged humpback whitefish from the three groups that were at large through a full year in this study were near 0.90 (Table 3). These values are at the upper end of the range of survival rates estimated by Fleming (1996). In addition, radio-tagging would not be expected to provide any survival advantage to a fish, and could be somewhat detrimental to a fish's survival compared to an un-tagged fish. Therefore, the survival rate figures obtained for the humpback whitefish in this study (Table 3) may be conservative estimates of the survival rate experienced by the population as a whole.

In any spawning population of high-fecundity fish, such as humpback whitefish, there are great numbers of young fish that experience very low survival rates (Hilborn and Walters 1992). For example, a female fish may produce 20,000 to 50,000 eggs (Townsend and Kepler 1974; Clark and Bernard 1988) during each of several spawning events during a life time. But to maintain a relatively steady population of adults, only two of these many thousands of eggs can reach maturity. If the upper Tanana River drainage were a primary rearing area for humpback whitefish, juveniles would be expected in greater abundance than adult fish in sampling efforts. However, few juvenile fish have been captured during the sampling events associated with the radio-tagging project, despite the fact that age 1 and older fish would have been vulnerable to the nets that were used. Nor were many juvenile fish captured in a previous systematic sampling project that occurred in 1998 (U.S. Fish and Wildlife Service, unpublished data). Their low abundance in catches from the upper drainage implies that they either reside in an upper drainage habitat that has not been sampled, or that they are somewhere else in the river system. Considering the extensive data presented by Naesje et al. (1986), Shestakov (1991), and Bogdanov et al. (1992), on downstream migrations of juvenile coregonid fish in Asian and Scandinavian rivers each spring, it seems reasonable to expect that a majority of juvenile humpback whitefish from the upper Tanana River migrate to rearing areas far downstream. If this is true, we might hypothesize that adult humpback whitefish recruit to lake habitats for feeding following their first spawning event. Given this scenario, the sample of radio-tagged fish in this study should be composed of adult fish that had already survived one or more previous spawning events.

The length distribution of radio-tagged fish from all sample sites combined was strikingly different than that from fish sampled in the Nabesna River spawning area (Figure 4). A large component of smaller fish was present in the spawning area sample, but was missing in the radio-tagged sample. If, as hypothesized above, the radio-tagged fish had previously spawned, then we should expect them to be larger than recently matured fish engaged in their first spawning event. Fleming (1996) points out that the minimum size of mature humpback whitefish in the Chatanika River was about 33 cm FL, which was the minimum size of spawning condition humpback whitefish captured in the Nabesna River spawning area in this study. The length distribution of fish sampled in the Nabesna River spawning area was broad enough to encompass the length distribution of the radio-tagged fish, suggesting that the population from which the radio-tagged fish were sampled was represented in the spawning area. The large component of smaller fish in the sample is, therefore, thought to be the result of an influx of recently matured fish engaged in their first spawning event. These fish presumably migrated to the spawning area from rearing habitats downstream.

Female humpback whitefish were nearly four times more abundant than males in the Nabesna River spawning area sample. The reason for this extreme female predominance in the sample is unclear, but similarly skewed sex ratios have been documented for other coregonid fish in the past. Brown (1970), for example, reported 87 to 97% females in samples of bloater *Coregonus hoyi* taken in Lake Michigan during the 1960s, when over 28,000 fish were examined, but could not explain the phenomenon. The predominance of females in the Nabesna River spawning area in this study will be considered as this study continues.

Further Investigation

Two major lake systems downstream of the current study area are scheduled to be investigated during the 2003 season (Figure 5). These lake systems are north of the Tanana River and are both connected to the river by stream channels. Mansfield Lake and its companion wetland system is approximately 132 km downstream from the confluence of the Nabesna and Chisana rivers. Healy Lake is another 95 km farther downstream. Humpback whitefish from Mansfield Lake are utilized by residents of the village of Tanacross, and those from Healy Lake are utilized by residents of the village of Healy Lake. The objectives of the 2003 radio-tagging work in these two lake systems are to identify spawning, feeding, and overwintering habitats used by these fish, and to document migratory timing and destinations. It is expected that radio-tagged fish will migrate to the spawning areas in the Nabesna and Chisana rivers. It may be that Healy Lake, for example, is a major rearing area for fish spawned in the upper river. In which case we might expect to see a large proportion of smaller fish, such as those sampled on the Nabesna River spawning area, preparing for a first spawning migration. However, rearing areas may be even farther downstream, and the smaller fish may not be found there.

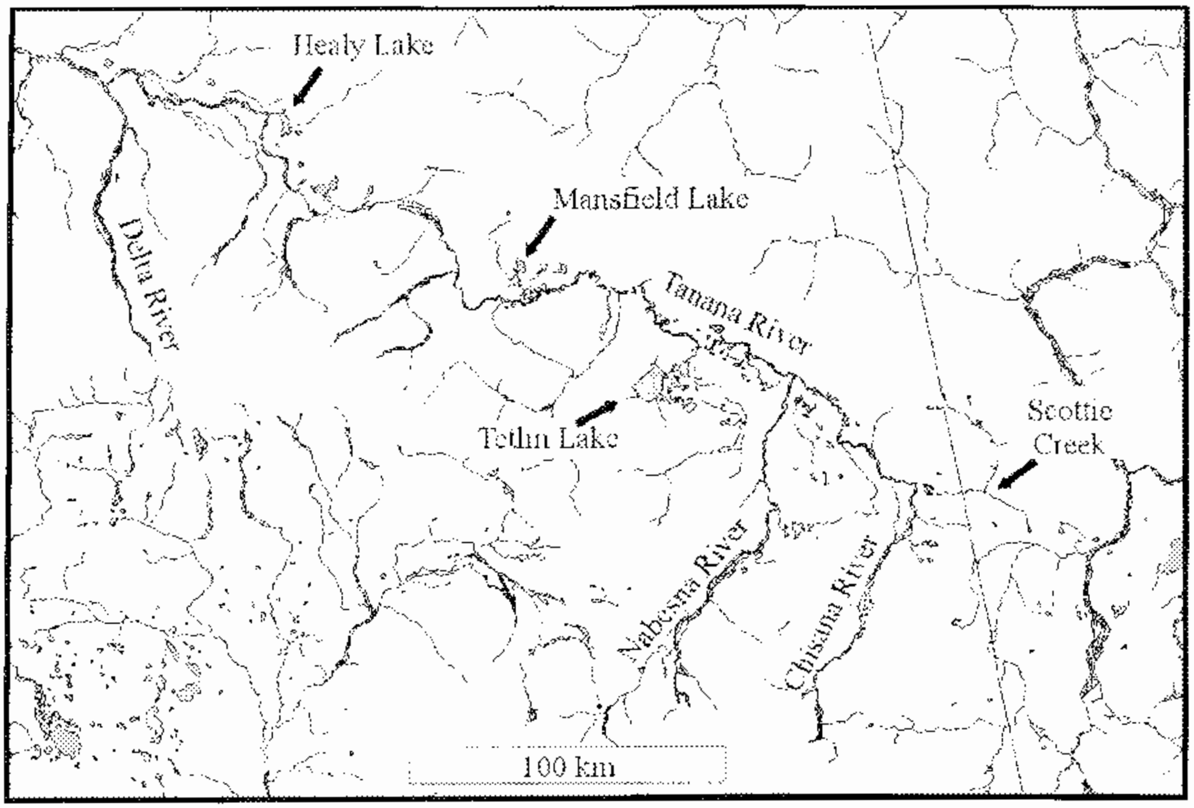

FIGURE 5.—An expanded view of the upper Tanana River drainage with pertinent geographic features labeled.

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